Design for Energy Efficiency in Residential Buildings

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Abstract: This paper presents the thermal design and heating design of an energy saving residential building in Beijing where the owners lived until 2004. Results show the advantages and disadvantages of a household-based heating mode by natural gas. Based on the quantity of natural gas by field tests in 2005, we conclude that thermal design influences heating design calculations.

Key words: residential building; heating mode by natural gas; thermal design; heating design calculation

1. FOREWORD

The activities of energy conservation were going on in China about 20 years. When building design standard was first issued in 1986, there is a large amount of energy-saving residence buildings accomplished all over the country (one-step conservation was about 1/3, two-step conservation was about 2/3) but still 35% non-energy-saving residence building. There exists a variance difference of over all heat transfer coefficient limitation of building envelop between developed countries and our country. It can be seen from the table below:

It can be seen that energy-saving efficiency in current energy conservation standard is about 50%, and even if carrying out smoothly, it may be the level of 1980's in developed countries. Now in the cities such as Beijing, Shanghai and Tianjin, who uses the 65% energy-saving standard it only reaches the level of 1990's in developed countries. So, we have a big difference but also a big potential.

We can use one energy-saving residence building to analyze its thermal and HVAC condition. It was accomplished conform to "Energy conservation design standard for new heating residential buildings"(JGJ26-95) and relative energy-saving efficiency was 50%.

Tab. 1 Difference of over all heat transfer coefficient limitation of building

	Exterior wall	Exterior window	Roof
65% energy-saving residence buildings in Beijing (>5 stories)	0.6	2.8	0.6
South of Sweden	0.17	2.5	0.12
Deutsch	0.3-0.2	1.5	0.20
USA (equal to degree days of heating period of Beijing)	0.45-0.32	2.04	0.19
Canadian	0.36	2.86	0.4-0.23

2. INTRODUCTION FOR ONE ENERGY-SAVING RESIDENTIAL BUILDING IN BEIJING

2.1 General Descriptions

It was located on Beijing west fourth ring road with 36967 m^2 construction area.

2.2 Indoor and Outdoor Design Conditions

Tab. 2 Outdoor

Outdoor dry bulb temperature, ℃	-9
Outdoor relative humidity	78%

Tab. 3 Indoor

Bedroom & living room temperature, ℃	20
Kitchen temperature,℃	16
Toilet temperature, ℃	23

2.3 Thermal Conditions

Its shape coefficient was 0.22.

① Exterior wall: 200mm thk. R.C.concrete, 10 mm thk. aero-interlining layer, 60 mm thk. gypsum

polyphenylene board (conduct coefficient is 0.07W/m • ℃), heat transfer coefficient of exterior wall (K) is 0.86W/m^2 • ℃ and the maximum value is 1.16 W/m^2 • ℃.

② Exterior window: single-layered double-glass plastic-steel side-hung window，heat transfer coefficient of exterior window (K) is 2.5W/m^2 • ℃ and the maximum value is 4.0 W/m^2 • ℃.

③ Non-heating staircase: 100mm thk. R.C.concrete, 10mm thk.aero-interlining layer, 100 mm thk.ceramsite block (conduct coefficient is 0.07W/m • ℃), heat transfer coefficient of wall (K) is 1.46W/m^2 • ℃ and the maximum value is 1.83 W/m^2 • ℃.

④ Partition wall: 100mm thk. R.C.concrete, 100 mm thk.ceramsite block (conduct coefficient is 0.07W/m • ℃), heat transfer coefficient of wall (K) is 1.65W/m^2 • ℃ and the maximum value is 1.83 W/m^2 • ℃.

⑤ Roof: 120mm thk. R.C.concrete, 80 mm thk cement polystyrene board(conduct coefficient is 0.058W/m • ℃), heat transfer coefficient of roof (K) is 0.56W/m^2 • ℃ and the maximum value is 0.8 W/m^2 • ℃.

⑥ Entrance door: heat transfer coefficient (K) is 2.0W/m^2 • ℃ and the maximum value is 2.0 W/m^2 • ℃.

⑦ Partition among heating rooms: 100mm thk. R.C.concrete, 20mm thk. polyphenylene board, heat transfer coefficient (K) is 0.91 W/m^2 • ℃.

2.4 Energy-saving Calculations

Index of heatloss of building is 15.61 W/m^2, Heating Load Index is 52 W/m^2.

2.5 Heating Design

The heat resource is gas furnace for flat. The heating system is one-pipe heating system and it is adopted surface-sighting radiators indoor and the temperature of supply water and return water is 78-58 ℃.

2.6 Advantages and Disadvantages by Using Gas Furnace for Flat

The system is a separated heating system in an apartment, use one or more gas boilers which use coal gas as fuel. The boiler heat the water of the heating system, at the same time, it offer hot water for life. The user can regulates the firepower of the boiler, thus controlling the temperature of water and room. This system is actually one versatilify billing method.

The system has some advantages :①The user can uses heating flexibly, regulate the room temperature only according to the using condition and has no limit; ②The boiler can provide heat and hot water; ③The main pipe can lay underground, without affect the indoor environment; ④The system solve the heating billing problem; ⑤The system can save the investment of out door heating pipe and the heating exchange station or boiler room. But this heating method have the applicable condition. The author think that the system is not suitable in very cold area for combinative apartment. The reason is as follow: ①The fire controlling: Because the boiler used coal-gas or natural gas is settled indoor, there have the danger and the explosion controlling is very difficult; ②Every boiler has separated flue, the heat efficiency is low, the combustion is often not complete, meanwhile, the Chinese gas quality is not good, this system may pollute the environment. With the increasing concern about the environment, this is the vital disadvantage of the development of gas boiler in heating system. ③The heat lavish: The design criteria of civil building energy saving (The part of resident) JGJ26-95 regulate that: the district heating system should choose the central heating system firstly. The separated gas-boiler system , wastes more energy because of its lower heating efficiency. Meanwhile, we must consider the heat transmission between apartments, thus increasing the heat load, wasting more energy; ④The investment of the boiler is higher. Because the water in heating system has not been dealed with , the furring may clot the pipe in some areas where the water quality is not good, the repair may be very difficult; ⑤There may have some damage of the indoor equipment (such as drain equipment)if the user has no heating ,especially in very cold areas.

This method was adoptive for those distributed residence buildings that central heating system can’t

reach, especially to those the temperature indoor often varied or living time in flat was disconnected.

2.7 Analysis of Using Gas in Energy-saving Residence Buildings

We take the "A" type flat of 100m^2 in this building as the example to analyze gas consumption in 12^{ve}, 2005.

"A" type flat heating layout as Fig.(gas furnace temperature is setup to the lower temperature for no resident at day. Due to the good heat preservation performance, indoor temperature still remain at 12℃ when owner return at night and it was between 18-20 ℃ from 9:00 pm to 7:00 am, it also remain this level when resident at home).

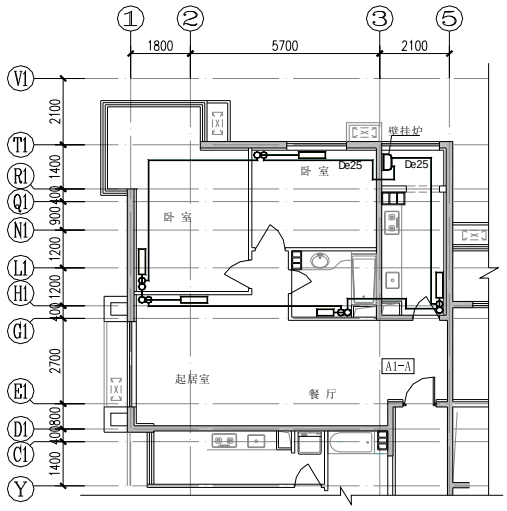

Fig . 1 "A" type flat heating layout

The gas consumption in 12^{ve}, 2005 was measured as showed in the table below (boldface represents the consumption occurred on Saturday and Sunday):

The design load of this flat was 70 W/m^2 (considering heat transfer among flats), and design load per day was 168 kW, if maximum efficient of gas furnace heat was 80-85% and calorific value of gas in Beijing is 9769W/m^3, the gas consumption per day will be 20.2-21.4m^3. But the mean consumption was 6.3 m^3/day according to statistics above and the coldest month in Beijing is January. There is another statistic we can use: in a heating season, the heating expenses that flat we use as a sample (include cooking and hot water for living) was 2200-2400 Yuan (it was stated over three heating seasons). If it has 125 days in a heating season and the heating expenses is 2400 Yuan, we can calculate out the expense of gas was 1.9 Yuan/m^3, so the gas consumption per day should be 10.1 m^3, which actual load is 35W/m^2.

Tab. 4 The gas consumption in 12/2005

Wastage / Time / Date	Gas card reading (m^3) 7:00 am	Gas card reading (m^3) 9:00 pm	Gas consumption (m^3) 7:00 am-9:00 pm	Gas consumption (m^3) 9:00 pm-7:00 am
12.3	1210	1204.8	5.2	2.8
12.4	1202	1196.2	5.8	2.9
12.5	1193.3	1190.4	2.9	5.4
12.6	1185	1182	3	1.2
12.7	1180.8	1177.4	3.4	2.5
12.8	1174.9	1172.9	2	3
12.9	1169.9	1167.1	2.8	1.8
12.10	1165.3	1162.2	3.1	2.1
12.11	1160.1	1156.9	3.2	3.7
12.12	1153.2	1146	7.2	2.3
12.13	1143.7	1141.9	1.8	3.6
12.14	1138.3	1135.8	2.5	2.2
12.15	1133.6	1131.8	1.8	4.6
12.16	1117.2	1123	4.2	1.4
12.17	1121.6	1120.1	1.5	5
12.18	1115.1	1110.1	5	1.9
12.19	1108.2	1104.6	3.6	3.3
12.20	1101.3	1099.6	1.7	4.9
12.21	1094.7	1092	2.7	2
12.22	1090	1087	3	2.1
12.23	1084.9	1082.6	2.3	3.6
12.24	1079	1073	6	1.5
12.25	1071.5	1068.8	2.7	6
12.26	1062.8	1057.2	5.6	2.4
12.27	1054.8	1049.2	5.6	2.1
12.28	1047.1	1045.5	1.6	5.2
12.29	1040.3	1037.1	3.2	2.9
12.30	1034.2	1031.7	2.5	4.4
12.31	1027.3	1024.5	2.8	
Sum of gas consumption (29 days) (m^3)			182.7	

3.THERMAL DESIGN HAS INFLUENCE ON HEATING DESIGN CALCULATION

With the modernization of building type, area of the envelop structure of light transmitting such as exterior window and glass curtain wall account high proportion on apparent surface. Due to multi-function of heat preservation and insulation, day lighting and absorbing sunshine, it becomes the main factor the influence the energy-consumption of building body. The developed countries got to attach importance to the new energy conservation technology of exterior window and glass curtain wall spreading out from 1990's. The technology of low-E coated glass frame and heating insulation glass curtain wall can effectively reduce long-wave eradiating and strength heat preservation and reduce the heating transfer factor from 5.4 W/m^2 to lower than 1.5 W/m^2. The heat loss of light transmitting structure was close to non-light transmitting structure and also has good nature day lighting and landscape. It can lessen sunlight eradiate from exterior window and glass curtain wall in summer. In winter, it let enough sunlight into house to take-in sunlight as one building heat source. The purpose of heat comfort can be attached in the way of using envelop structure take-in and store sunlight to avoid too high temperature at day and release heat to reduce temperature downing and conserve heat.

The accomplished house that conform to "Energy conservation design standard for new heating residential buildings" (JGJ26-95) can reach the temperature that design required, which it utilize sunlight in south room in non-heating condition if it is sunny at day and heat storing at night. In the situation of high energy conservation, heat load calculation and optimization of heating system is not going deeply, so equipment selecting and system designing often makes more energy consumption than actual consumption and caused too much energy wasting. We in fact find a lot of energy-saving residence buildings (energy-saving efficient was 50%) whose south room radiators work in a short time in heating season. This phenomenal is not for heat transfer among flats at all and the author considers reason as the heat from sunlight and flat heat storing. We should consider influence on thermal design and heat storing in heating design calculation . It is one of way to install temperature control valve in radiator to adjust hot water flow. It will more study in energy conservation system.

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